
A Glimpse into How People Use Novel Technology in Homes

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Abstract

We conducted an interview and diary study with ten households in order to investigate participants' adoption and use of a 'smart' thermostat in the home. In this paper, we reflect on our use of the diary study method for data collection and present key challenges and benefits of using a free note-taking application as a diary and data submission tool.

Author Keywords

Diary study, Home, Methods

ACM Classification Keywords

H.5.2. User Interfaces: Theory and Methods

Introduction

In order to better understand the opportunities and challenges of intelligent systems in the home, we studied the experience of living with an advanced thermostat, the Nest, which utilizes emerging technology such as machine learning, motion sensing, remote access and energy consumption monitoring. Using the Nest as a lens, our study investigated the user experience of living with a 'smart' domestic appliance, particularly one that sought to help people manage their home energy consumption more effectively.

In the remainder of this paper, we describe how we collected data and discuss the challenges with maintaining participants' involvement, the quality and

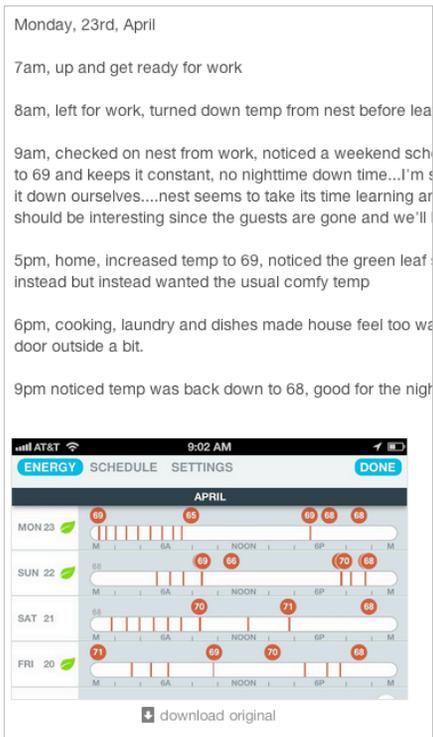


Figure 1. A screenshot of one of the participants' diary entry. The participant described her family schedules and how she and her husband interacted with the Nest. She also uploaded screenshots of the Nest mobile interface, Nest schedule, and Energy History.

quantity of diary entries, and observing the experiences of different house occupants.

Method

Our study collected three different types of data from our participants: (1) daily diary entries for three weeks (2) three interviews: a pre-study interview, a brief mid-study interview, and a longer post-study interview after completion of the study and (3) screenshots of the Nest's 'Energy History' (Figure 1) which showed the history of temperature settings and heating and cooling status during the study period.

We chose to use a diary study method as the central part of our data collection. Diary studies offer an inexpensive and ecologically valid way of allowing participants to document daily activities [3]. It is particularly beneficial for examining "experiences in their natural, spontaneous context" [1]. In our study, we additionally grounded the diary entries and interviews with automatically generated logs of thermostat control operations, thus providing a third stream of data representing participant behavior.

Our study started with an initial interview during which we asked about how participants used their previous thermostat as compared to the Nest, as well as their overall experience and understanding of the Nest. After ten days, we conducted a mid-study interview, during which we discussed participants' diary entries up to that point. For the final interview, we discussed participants' later diary entries and any overall experiences and changes in their perceptions or behaviors for entire study period. Interviews allowed us to obtain better insight into the reasoning behind participants' behavior and opinions.

For each diary entry (an example shown in Figure 1), we asked participants to report daily routines, changes made to the thermostat, and reactions to the Nest. The participants recorded their diary entries using a free web and mobile note-taking application, Catch, which allowed users to create and share text, photos, and voice notes. We provided example diary entries but did not provide prompt questions for diary entries. Once a week, we asked participants to upload screenshots of the Nest schedule and Energy History. These views were available via the Nest thermostat web or mobile application and participants took screenshots of them and submitted them via Catch. Using Catch's commenting features, we occasionally left comments on diary entries to encourage participation and ask for clarification regarding what they wrote in their entries. While overall experiences and opinions were reported from the interview, the diary entries provided opportunities for us to observe participants routine and non-routine use of the Nest over time, and obtain more details about different contexts, factors or triggers for participants' actions (e.g. changing the temperature setting).

Lessons Learned

In this section, we discuss methodological challenges and opportunities we learned from our diary study. In particular, we found challenges with maintaining participants' commitment over a three-week diary period, gathering high quality and quantity data, and capturing the experiences of multiple house occupants. Additionally, we found that the Catch online note-taking tool was effective at reducing the burden on the researcher as she sought to manage multiple study sites at the same time.

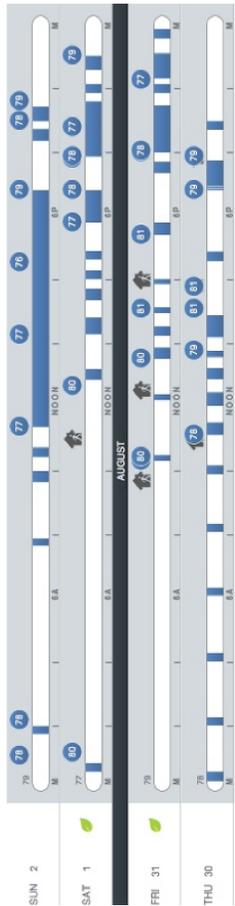


Figure 2. The Energy History is automatically generated by the Nest thermostat and available via participants' Nest account online. It shows a detailed history of temperature setting (blue circle) and how long heating or cooling operated (blue bar for cooling) for each day up to 10 days.

Motivating Participants to Write Often and More

One of the main challenges for diary studies is to encourage participants to report to their diary on a regular basis [1,2,3]. Palen *et al.* stated that researchers' involvement is helpful to maintain participants' motivation to report [3]. In order to encourage our participants to write regularly and in detail, we occasionally left comments on participants' diary entries to signal that we were paying attention to their diary entries and appreciated their contribution. The ability to leave comments was enabled by the specific tool we used (Catch), but we felt that this capability was useful and we would look for similar capabilities in future studies. We regulated our comments to a brief acknowledgment of what they wrote and asked for clarification when we did not understand what they wrote. We deferred detailed questions until the interviews. For future studies, we may consider using the comment tool even more actively to maintain an on-going and asynchronous communication with participants in a non-disruptive way. We speculate that the comment function could be a useful way to obtain more detailed data from participants by asking follow up questions on specific occasions the researcher finds interesting or when participants fail to provide sufficient data, perhaps supplanting the role of interviews in whole or in part. However, it should be acknowledged that researchers' comments might influence what participants report in their diaries (they may say what they think the researcher wants to hear) or even change the way they interact with their thermostats.

Utilizing the Automatically Generated Log

It was greatly beneficial for researchers and participants alike to utilize the log of temperature

changes obtained from Nest's Energy History (Figure 2). In addition to screenshots of the log data, participants provided a more contextualized explanation of the changes by writing a diary entry. Especially for the researcher, it is crucial to obtain a detailed explanation of the situations and reasons behind participants' actions during the interview because the log data do not tell the whole story about the temperature changes. Both participants and the researcher benefitted from having automatic log data: the log data helped participants to remember changes they made, and the researcher could see the actual interaction of the participant with the thermostat and ask questions if there was a potentially interesting change of pattern. In order to provide a more effective way for participants to report detailed information in their daily entries, we thought it would be useful if we had a simple annotation tool where participants could write descriptions on the log data itself without having to refer to the event in a separate text (in our case, screenshots of the Energy History attached in diary entry, shown in Figure 1). If participants did not remember or chose not to report their history, we were unable to view the log data and had to rely on participants' recall and what they reported. We could have accessed the log data if we had asked participants for the login information of their Nest account. However, we did not collect such information because we felt it was sensitive information and it might deter participation. In retrospect, however, we think it would have been worth exploring the acceptability of gaining direct access to participants' Nest accounts.

Representing Other House Occupants

In each household, we mainly interacted with a single household member, whom we call our "primary

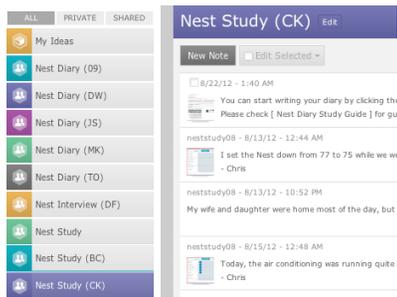


Figure 3. The screen view of researcher's 'Catch' note-taking application: On the left, the list of participants' shared diary folders is shown. An icon will be shown to notify a new update for each folder. On the right, the list of diary entries from a selected participant is shown.

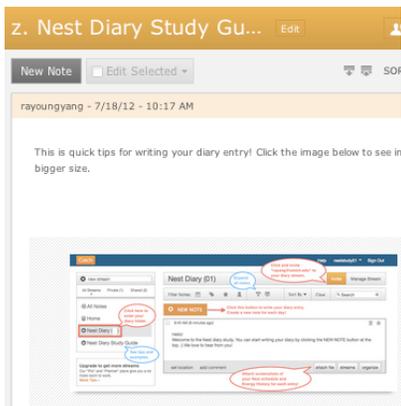


Figure 4. One of the posts from the researcher, which explains how to use the 'Catch' note-taking application for diary reporting and attaching screenshots, is shown.

participant." Our primary participants were responsible for reporting diary entries and participated in all three interviews. Generally, our primary participants were the main controllers of the Nest in their respective homes, and so the diary entries pretty well covered the house occupants' interactions with the Nest. However, it was found that having one family member reporting their activity limited our knowledge regarding the behaviors of other occupants. Since it was difficult to recruit all house occupants to participate in a three-week diary study, we chose to conduct additional interviews with other house occupants where possible. We were able to interview a secondary participant from four households out of ten. It was illuminating to learn about other occupants' experience with the Nest and we would like to explore this angle more deeply in the future.

In the future, we feel it would be beneficial to find ways to motivate other house occupants to contribute to the diary entries in order to better understand the experience of the whole household.

Reducing Burden for the Researcher

Two researchers worked on this study and one researcher was solely dedicated to conducting diary study data collection and analysis. Using a free note-taking application significantly reduced the amount of time and effort needed for the researcher to develop a diary tool. Since Catch provided both web and mobile versions of the application, participants could access their diary tool using different devices anytime. With the benefit of having a comments tool and a sharing option in the note-taking application, one researcher could manage a three-week long diary study with ten households. Each participant's Catch folder was shared with the researcher, and the researcher could view all participants' diary reporting folders on one screen as

well as get notification when a diary was updated (Figure 3). As described above, comments could be added to each diary entry, making it easier for the researcher to pose questions about the participant's entry. During interviews, participants and the researcher could view the reported entries together remotely and discuss what they wrote. Overall, the tool we used made it easier for one researcher to monitor diary reporting of ten households, make comments to motivate participants to report, send reminders or announcements to participants (Figure 4), and acted as a memory aid for participants and researchers to review the diary entry during the interview.

Conclusion

In this paper, we described our use of the diary study method for data collection and reflected on challenges and opportunities in using a free note-taking application as a diary and data submission tool. We highlighted the benefits of the automatic log history and an online note-taking application as a way of increasing participants' involvement and reducing the burden put on the researcher.

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